Research on emergency supplies distribution in 5G network environment based on TSP model

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Abstract. Along with the improvement of technology and the gradual popularization of 5G network, the application of UAVs is becoming more and more widespread, and the delivery mode of "delivery vehicle + UAV" has gradually become a new and effective delivery method. In order to solve the real problem of emergency supplies to be delivered to the disaster area after the disaster and to improve the efficiency of emergency supplies delivery, this new and effective delivery mode is used to solve the delivery problem. In this paper, a TSP model based on Floyd algorithm and genetic algorithm is established and the optimal distribution scheme is given. In the delivery mode of "delivery vehicle + UAV", the individual evaluation function is improved, and the flight conditions of UAV are introduced, and the optimal delivery scheme is given by simulation selection, crossover and variation. In the mode of "delivery vehicle + UAV" and the delivery vehicle has a single weight limit of 500 kg, The optimal solution is given for single "delivery vehicle + UAV" and the optimal solution is given for a single "delivery vehicle + UAV" and a double "delivery vehicle + UAV".

Keywords: Floyd algorithm, Genetic algorithm, TSP model, k-means clustering.

1. Introduction

China is in a period of high incidence of emergencies, the current global epidemic is rampant, various emergencies are emerging, causing huge casualties and economic losses. According to the National Disaster Reduction Network [1], in April 2022 alone, natural disasters in China were mainly wind and hail, floods, geological disasters, low-temperature freezing disasters, earthquakes, droughts, snowstorms, forest and grassland fires also occurred to varying degrees. Various natural disasters caused a total of 2.254 million people affected, 13 people dead and missing due to the disaster, more than 400 collapsed houses, more than 1700 seriously damaged houses, general damage 31,000; crop disaster area of 250.9 thousand hectares; direct economic losses of 2.8 billion yuan. Due to the uncertainty, suddenness and destructive nature of emergencies, it often causes urgent needs for supplies and difficulties in the lives of victims in the disaster area. Therefore, how to distribute emergency supplies to the control area as soon as possible and further improve the distribution efficiency of emergency supplies has become one of the important issues of emergency management in China. In the actual emergency relief work, different disaster sites differ in disaster conditions, environment, population and other factors, and the severity of the disaster and the urgency of the demand for supplies are also different, coupled with the time requirements for raising emergency resources, it is often necessary to consider the time requirements for the distribution of emergency supplies to control sites, so as to develop a scientific distribution route planning scheme, so that the abnormal areas in a shorter period of time to obtain the corresponding emergency supplies as much as possible. The distribution route planning plan should be developed so that the emergency supplies can be obtained in the shortest possible time.

The Traveling salesman problem (TSP) is a well-known problem in the field of combinatorial optimization [2], with a wide range of engineering and real life applications, such as the arrangement of aircraft routes, circuit drilling, road networks, supermarket shelves, the setting of communication nodes, logistics goods distribution, etc. All these practical applications can be applied to the TSP

model. Thus, it is of great practical value to solve TSP problems efficiently and rapidly. Currently, with the booming development of artificial intelligence, many intelligent optimization algorithms have been applied to TSP problems. Many scholars have studied ant colony algorithms [3], genetic algorithms [4-6], simulated annealing algorithms, heuristic algorithms [7], neural networks, particle swarm optimization algorithms, immune algorithms, and so on. Liu [8] et al. proposed a TSP model combining genetic algorithm and machine learning, which is a very interesting model.

With the improvement of technology and the gradual popularization of 5G network, the application of UAVs is becoming more and more widespread, and the delivery mode of "delivery vehicle + UAV" is gradually becoming a new effective delivery method.

This paper draws on a variety of approaches and models to solve the problem of vehicle-based delivery mode. The "delivery vehicle + UAV" delivery model. The maximum load of the distribution vehicle is 500 kg, which is the optimal solution for distribution. So that the "delivery vehicle + UAV" delivery mode can complete a whole delivery in the shortest time.

2. Model assumptions and symbols

2.1. Model assumptions

Assumption 1: There is no traffic jam during the delivery of material vehicles, and the whole journey is maintained at a uniform rate of motion.

Assumption 2: Each UAV has stable power consumption, and there is no abnormal behavior when the power is low.

Assumption 3: The pilot is skilled and does not need to rest throughout the whole process.

Assumption 4: The UAV will not be disturbed by other factors, including the distance from the remote control, weather conditions, etc.

2.2. Symbols

The symbols are described in Table 1.

Table 1. Symbol Description

Symbols	Meaning
n	Number of locations
d_{ij}	Distance from location i to location j
M_c	Maximum load of material truck
M_d	Maximum load of UAV
V_c	Delivery vehicle speed
V_d	UAV Speed
$S_{\max}$	UAV flight miles
f_i	Individual assessment indicators
p_i	Environmental adaptation rate
u	Vehicle delivery locations
v	UAV delivery locations
N	Number of individuals in the population
$N_{\max}$	Maximum number of iterations
ρ_c	Crossover Rate
ρ_v	Mutation rate

3. Model construction and solving

3.1. TSP model based on genetic algorithm and Floyd algorithm

To build the traveler's mathematical planning model (TSP), let x_{ij} = 0" or 1", where 1 means the road taken from location i to location j, and 0 means no choice to take this road, then we have.

$$\min \sum_{i \neq j} d_{ij} x_{ij}.$$

$$\text{s.t.} \begin{cases} \sum_{i=1}^{n} x_{ij} = 1, i = 1, 2, \cdots, n \\ \sum_{i=1}^{n} x_{ij} = 1, j = 1, 2, \cdots, n \\ \sum_{i,j \in S} x_{ij} \leqslant |s| - 1, 2 \leqslant |s| \leqslant n - 1, s \subset \{1, 2, \cdots, n\} \\ x_{ij} \in \{0, 1\}, i, j = 1, 2, \cdots, n, i \neq j \end{cases} \tag{1}$$

Solving the TSP problem using genetic algorithm.

Step1: Encoding

The result of the TSP problem is to select nodes (which can be repeated) in 1-14 to form a sequence of closed paths, so assume that the encoding is x_1 x_2...x_{20}, where x_1=x_{20}=9, and the remaining nodes are selected in {1,2,...14}\9. Since the number of repetitive paths is inevitably small, we first need to randomly select 13 nodes to form a full arrangement of {1,2,...14}\9, and then select the numbers in the remaining positions to form a reasonable encoding.

Step2: Generate the initial population

Generate an initial population that meets the requirements. Usually, it is required that the individual codes in the initial population can form a closed loop, i.e., $d_{x_i x_{i+1}} > 0$, which holds for $\forall i = \{1,2, \ldots 19\}$.

Step3: Individual evaluation fitness function

If an individual can form a complete closed loop, let the individual evaluation value $f_i = \sum_{i=1}^{19} d_{x_i x_{i+1}}$. If the closed loop cannot be formed, the individual evaluation value $f_i = inf$, and the fitness function of the individual is $\frac{1}{f_i}$.

Step4: Individual selection

The selection of individuals is usually done by roulette wheel method. Let the population size be n, and the fitness of individual i be F_i, then the probability that the individual of this species survives to the next generation is.

$$p_i = \frac{F_i}{\sum_j F_j} \tag{2}$$

Generate a random number $k \sim U(0,1)$, if $k > p_i$, the individual will be inherited to the next generation population.

Step5: Crossover operation

Using a single-point crossover scheme, the population is firstly randomly paired, then the position of the crossover point is set, and then some genes are exchanged between chromosomes.

Step6: Mutation operation

To alter certain genes that cannot form a closed loop. The location of the mutation point was first identified, and then the numbers were mutated so that the gene can form a closed circuit.

Using Matlab software, the optimal solution is obtained by considering only the distribution of the delivery vehicle.

Path order:

9→13→14→10→6→4→6→5→2→3→5→7→1→11→12→8→9.

Shortest distance: 582 km.

Delivery time: 11.64 hours

The iterations of the algorithm are as shown in Figure 1. The route of the delivery vehicle is shown in Figure 2.

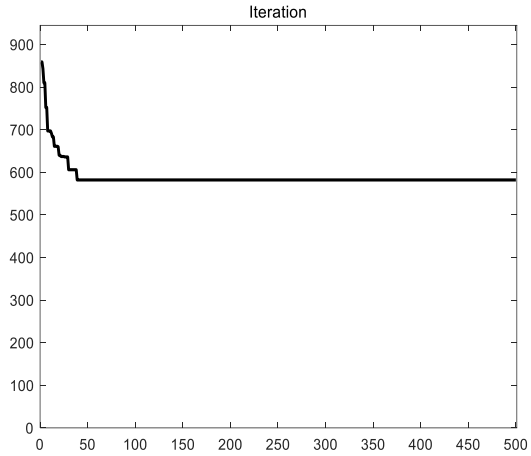


Figure 1. Number of iterations

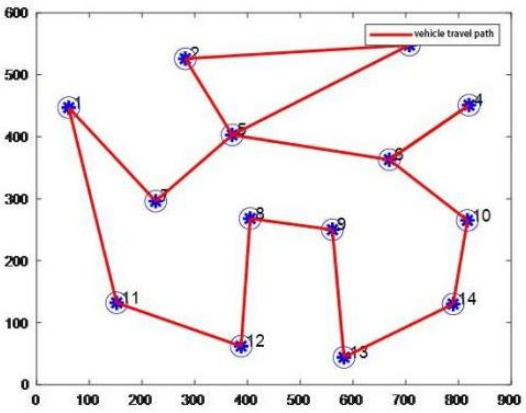


Figure 2. Material vehicle travel path

3.2. TSP model with changing evaluation function

Use genetic algorithm to solve this subproblem. Assume that the ordered set of points through which the vehicle passes is *U* and the ordered set of points through which the UAV passes is *V*. Then $U \cup V = 1,2,\ldots,14, U \cap V = \phi$. Since the UAV has a load of 50 kg, therefore 2,5,7,9,10∉V. Since the required material at point 8 is 50 kg, if it is delivered by the UAV, then the UAV can only deliver to this point, but not to other points. However, the speed of the UAV is faster than that of the vehicle, so the vehicle has to wait and spend more time, so $8 \notin V$. Then the possible points of U are 1,3,4,6,11,12,13,14, a total of 8 cases, which are denoted as p_i point.

Step 1. Encoding

Encode the 8 cases of possible points of U into binary numbers $x_1x_2x_3x_4x_5x_6x_7x_8, x_i \in \{0,1\}$. $x_i = 1$ means the vehicle passes through point p_i, and vice versa, it does not pass through point p_i.

Step 2. Individual adaptation function

To evaluate the population individuals, for this problem, we need to calculate the global time required for a vehicle to pass through point *U* and for a vehicle plus a UAV. The initial population size *N*=200.

(1) Calculate the best path for the vehicle to pass through the *U* point, using the same algorithm given in the first problem. In this case, the vehicle may not be able to form a closed loop if it only passes through the *U* point. For this case there are two options, one is to define the required time as inf and discard the individuals. The other is to consider the node *NF* that cannot form a closed loop,

and use Floyd algorithm to solve the global shortest path from *NF* to *U*, and add the point *M* passed in the shortest path to *U*, and remove it from *V*, and solve the required minimum time again, at this time $U'=U \cup M$, $V'=V \backslash M$. In this paper, we choose the latter.

(2) Calculate the optimal path of the UAV through all *V'* points.

(3) Calculate the time required for the best path.

Step 3. Selection operation

The population is selected, and among the parent and offspring populations, the good traits are selected to survive, in this case, the individuals with shorter evaluation time. Among the individuals with unadapted traits, a certain percentage of them are also selected to survive.

Step 4. Crossover operation

In this case, a single point crossover is used, where two parents f, f' are selected, corresponding to the chromosome structure $f = x_1x_2x_3x_4x_5x_6x_7x_8$. The crossover point k is chosen randomly so that the first *k* sequences of the chromosomes of the offspring are composed of the positions corresponding to *f*, and the remaining chromosomes are composed of the positions corresponding to *f'*. The selection of parents for the crossover operation is usually based on superior traits.

Step 5. Mutation operation

Randomly selecting individual *f* and changing the state parameters of 2-3 positions of individuals to achieve population diversification is the guarantee for the model to be able to find a globally optimal solution.

Use Matlab to solve the route order of delivery vehicle:

$$9 \rightarrow 8 \rightarrow 7 \rightarrow 5 \rightarrow 2 \rightarrow 5 \rightarrow 6 \rightarrow 10 \rightarrow 9.$$

UAV path order:

$$9 \rightarrow 13 \rightarrow 8,$$

$$8 \rightarrow 12 \rightarrow 7,$$

$$7 \rightarrow 11 \rightarrow 1 \rightarrow 2,$$

$$6 \rightarrow 3 \rightarrow 4 \rightarrow 10,$$

$$10 \rightarrow 14 \rightarrow 9.$$

Delivery time: 6.28 hours

The specific route planning is shown in Figure 3.

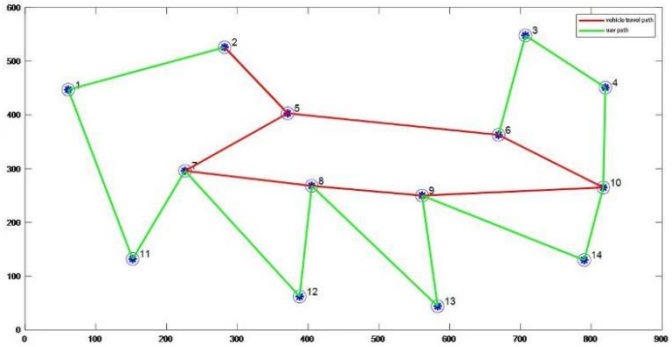


Figure 3. Route Map

3.3. K-means clustering TSP model

Based on the k-means clustering method [9], the graph is clustered into two parts E_1 and E_2 so that the sum of the distances from all points to the cluster centers in the same cluster is minimized. It is necessary to classify the concentration point 9 into two clusters, so that when the transport truck is empty, it returns to the transport point for the second transport.

The algorithm in Part 3.2 is used to solve for E_1 and E_2 respectively. By adding the minimum time required, the time taken for a complete transport is obtained.

Using Matlab, k-means clustering is implemented, and the results of clustering E_1, E_2 are obtained as follows.

$$E_1=\{1,2,3,5,7,9\},E_2=\{4,6,8,9,10,11,12,13,14\} \quad (3)$$

The clustering diagram is shown in Figure 4, and the algorithm in Part 3.2 is used to solve for E_1 and E_2 respectively. The minimum time is 6.8 hours. The specific vehicle and UAV flight path results and visualization results are shown in Figure 5.

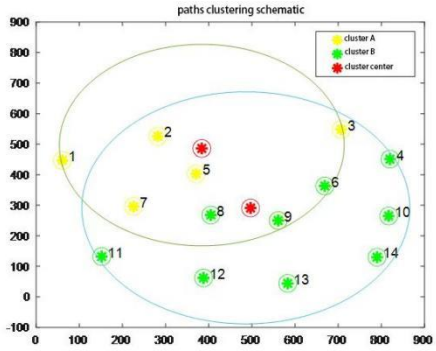


Figure 4. k-means clustering schematic

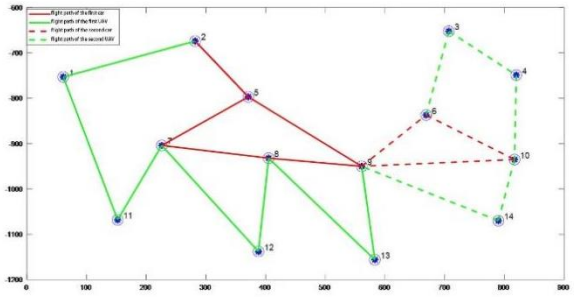


Figure 5. Paths

First round of transportation:
Route order of material trucks:

$$9\rightarrow8\rightarrow7\rightarrow5\rightarrow2\rightarrow5\rightarrow9.$$

UAV route sequence:

$$9\rightarrow13\rightarrow8,$$

$$8\rightarrow12\rightarrow7,$$

$$7\rightarrow11\rightarrow1\rightarrow2,$$

Total weight: 494 kg
Second round of transportation:

$$9\rightarrow6\rightarrow10\rightarrow9.$$

UAV route sequence.

$$6\rightarrow3\rightarrow4\rightarrow10,$$

$$10\rightarrow14\rightarrow9.$$

Total weight: 238 kg
Total delivery time: 6.8 hours

3.4. Adopting the "delivery vehicle + UAV" delivery model

Based on the k-means algorithm, the 30 locations are analyzed in 2 clusters such that one of the points is location 9 and the center of the other class is chosen as the material concentration point. Each class then starts from the material transportation center and completes the transportation problem within the class. Since the load is 500 kg, the problem solves the distribution path of the respective class requires the use of a secondary transportation scheme, i.e., a secondary clustering of regions to determine the locations that need to be distributed for each transport.

Using Matlab, k-means clustering is implemented to obtain the clusters $E_a = E_1 \cup E_3$, $E_b = E_2 \cup E_4$.

$$E_1 = \{1, 7, 9, 11, 18\},\ E_2 = \{15, 16, 17, 19, 20, 21, 22, 24, 25\} \tag{4}$$

$$E_3 = \{2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14\}, E_2 = \{20, 23, 26, 27, 28, 29, 30\} \tag{5}$$

Since the weight in the area is more than 500kg, we need to use the algorithm of part3.3 for the second distribution. The clustering result of class E_a is E_1, E_3, and the clustering result of class E_b is E_2, E_4. The clustering centers are location 9 and location 20, so the material concentration point is selected as location 20, and the clustering diagram is shown in Figure 6.

The specific distribution routes are as follows.

The driving path of the first car.

9→12→11→1→7→8→9,

9→5→2→5→6→10→9.

Flight path of the first UAV:

9→13→9,

11→18→11,

6→3→4→10,

10→14→9.

Flight path of the second car:

20→25→16→20,

20→21→22→27→26→30→26→20.

Flight path of the second UAV:

25→15→16,

25→24→19→24→25,

20→21→20,

22→17→22,

22→23→27,

27→28→26,

30→29→30,

Minimum delivery time: 9.58 hours.

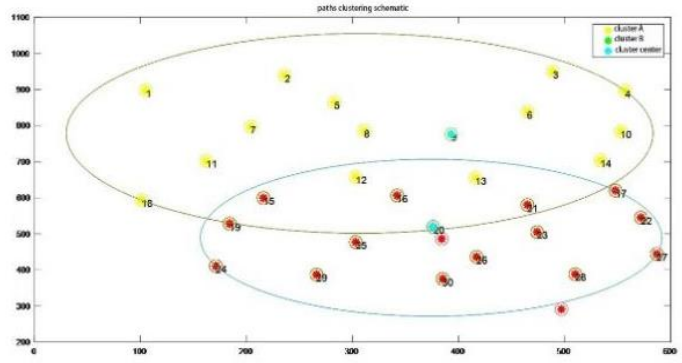


Figure 6. Clustering schematic

The path schematic is shown in Figure 7.

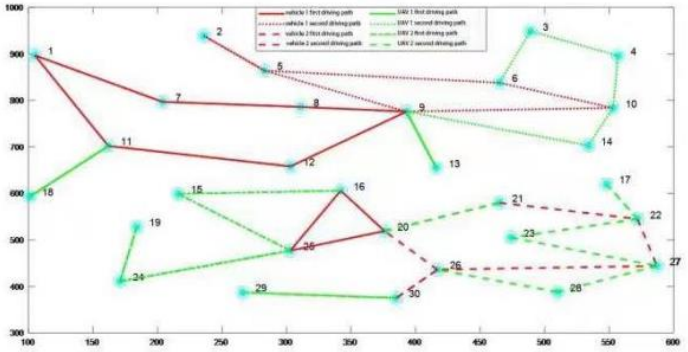


Figure 7. Route Planning

4. Conclusion

The Floyd algorithm used in this paper is applicable to APSP (multi-source shortest path) [10], which is a dynamic programming algorithm that works best for dense graphs with positive or negative edge weights. This algorithm is simple and efficient, and due to the compact structure of the triple loop, it is more efficient for dense graphs than Dijkstra's algorithm, which performs |V| times, and SPFA algorithm, which performs |V| times. For this problem, it is applied to traverse the shortest circuit, which reduces the complexity of the code and simplifies the execution process. Using a highly cohesive and low coupling model solution process, the TSP model based on the genetic algorithm and Floyd algorithm has a clear block logic, high execution efficiency, low repetition of code functions, and clear results, which is very suitable for solving this type of shortest-circuit problem and, with modifications, for finding the best location for the concentration of emergency supplies, which reflects the reusability and portability of the model. However, the implementation of the genetic algorithm coding is complex and requires coding of the problem and decoding even after finding the optimal solution. The implementation of the three parameters is stochastic, and it is difficult to choose the appropriate crossover rate and mutation rate to make the algorithm converge to the global optimal solution, and these two rates need to be adjusted continuously.

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